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AQUATIC INVESTIGATION ON THE COLORADO RIVER FROM SEPARATION CANYON TO THE GRAND CLIFFS, GRAND CANYON NATIONAL PARK

James E. Deacon and John R. Baker

Technical Report No. 15

Colorado River Research Program

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COLORADO RIVER RESEARCH PROGRAM
Grand Canyon National Park
Grand Canyon, Arizona 86023

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AQUATIC INVESTIGATION ON THE COLORADO RIVER FROM SEPARATION CANYON TO THE GRAND CLIFFS, GRAND CANYON NATIONAL PARK

Submitted to

GRAND CANYON NATIONAL PARK
NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

by

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ABSTRACT

Physical, chemical and biological data were collected from two sites between Separation Rapids and Pierce Ferry for a ten month period. The purpose of the study was to examine limnological effects of the Colorado River in relation to Lake Mead and to supplement other research on the Colorado River.

Water temperatures were 2^{o} to 10^{o}C cooler than those reported before the closure of Glen Canyon Dam. Cooler water temperatures have probably changed the density relationship between the Colorado River and Lake Mead, changing current patterns and limnological conditions in Lake Mead.

Dissolved oxygen levels, nutrient concentrations, and bacteria numbers generally indicate natural unpolluted conditions. High phosphorus (greater than 300 ug/1) and total coliform concentrations (1160/100ml) found on 4 January were exceptions and may have been due to a large organic load discharged into the Colorado River. It is suggested that sewage effluent from visitor use has minimal overall effects on the water quality in the Colorado River due to dilution and biological decay, but potential health hazards may exist at some camp sites.

Primary productivity is extremely variable and generally shows an inverse relationship with turbidity. Colorado River water is potentially very productive but it is limited by light due to suspended material. Higher productivity would probably be undesirable due to the possibility of phytoplankton blooms and increased periphyton growth.

Ten species of fish were collected from various locations. Rhinichthys osculus, Catostomus latipinnis, and Pantosteus discobolus were the only native fish collected.

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INTRODUCTION

Physical, chemical, and biological conditions in the Colorado River between Separation Rapids and Pierce Ferry were investigated for a ten month period (September 1975 through June 1976). Parameters measured as part of the investigation were water temperature, dissolved oxygen, conductivity, hydrogen ion (pH), turbidity, plant nutrients (phosphorus and nitrogen compounds) primary productivity, phytoplankton biomass, and bacteria numbers. Fish were collected from the main stream and tributaries. In addition, biological oxygen demand (BOD) and chemical oxygen demand (COD) were determined and a collection of flowering plants from Spencer Canyon was made.

The purpose of the study was to examine limnological effects of the Colorado River in relation to Lake Mead and to supplement other research on the Colorado River above Separation Rapids. Prior data have mainly been restricted to physical and chemical conditions (Anderson and Pritchard, 1951; Lara and Sanders, 1971; Smith et al., 1960) and very little information exists on biological conditions. Information from this study and others conducted above Separation Rapids will provide baseline data to assess the effects of recreational use within the canyon and any future changes which may occur.

METHODS

Two permanent collection stations were established at Pierce Ferry and at Burnt Canyon (Mile 259). The above sites were selected because Pierce Ferry was representative of lake-like conditions directly influenced by the Colorado River and Burnt Canyon was typical of the river within the study area. Samples were collected on the following dates: 27 September, 25-26 October, 29-30 November, 3-4 January, 27-28 January, 6-7 March, 29-31 March, 24-25 April, 23-25 May and 10 June.

Water samples for chemical, phytoplankton, and bacterial analysis were integrated samples. At Pierce Ferry, water samples were taken from surface to bottom (7 meters) with an electrical water pump. Samples collected at Burnt Canyon were a combination of three separate, one-liter subsamples taken with a Van Dorn water sampler. Water samples for nutrient analysis were preserved in $HgCl_2$ and transported to the laboratory. Bacterial samples were collected in a ten-liter stainless steel container, previously sanitized with acetone-alcohol. A three-liter sample was held on ice and returned to the laboratory for phytoplankton analysis and other chemical determinations.

Nutrient analyses were performed by the Land and Water Monitoring Branch of EPA. Analysis included total phosphorus, dissolved phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, Kjeldahl nitrogen, and total alkalinity.

Suspended solids and chemical oxygen demand were determined based on procedures in Standard Methods for the Examination of Waste and Waste Water, 13th ed. (American Public Health Association et al., 1971). Biological oxygen demand was determined using a Hach Manometric BOD Apparatus. Turbidity measurements were taken with a Hach Model 2100A Tubidimeter. Temperature, dissolved oxygen, conductivity and pH measurements were taken with a Model IIA Water Quality Analyzer (Hydrolab Corporation). The analyzer was calibrated prior to each collecting trip.

Total bacteria and total coliform bacteria were determined according to the membrane filter procedures in Standard Methods for the Examination of Waste and Waste Water. Filtration was performed in the field using 0.45 u pore size membrane filters. The samples were incubated in portable incubators in the field and then transferred to laboratory incubators. Water samples, taken on 6 March through 10 June, were blended using a Panasonic MX 280 Blender.

Total coliform counts were determined for five duplicate dilutions of 100, 10, and 1 ml. Total coliform plates were saturated with 2 ml M-Endo Broth (Difco) for samples collected on 27 September through 28 January, and incubated at 35°C. Due to difficulty in maintaining a constant temperature of 35° with the portable incubators, Coliform Holding Media (CHM) was used from 6 March through 10 June. Sample filters were transferred to M-Endo Broth in the laboratory. Coliform counts were made after the 24 hour incubation period.

Total bacteria counts were determined for five duplicate dilutions of 1, 0.1, 0.01, 0.001, and 0.0001 ml.

Total bacteria plates were saturated with 2 ml of tryptone glucose extract broth. Counts were made after a 5 day incubation period of 25°C.

Phytoplankton enumerations were made on samples using a modification of the membrane filter technique (McNabb, 1960). Suspended material made identifications and counting difficult and, therefore, only the dominant organisms are reported.

Chlorophyll analyses were made on 500 to 1000 ml samples filtered through Watman GF/C filters. The chlorophyll was extracted by grinding the filters in 5 ml of acetone. Pigment concentrations were determined from formulas given by Parsons and Strickland (1963) using data obtained with a Coleman Junior Spectrophotometer.

Estimations of primary productivity were made at Pierce Ferry based on the carbon-14 technique (Steeman Nielsen, 1951) using modifications of Saunders et al. (1962). Light and dark bottles were filled with water collected at the surface to the depth of the euphotic zone, determined by using a Submarine Photometer (Kahlsico). Each bottle was spiked with 0.5 uCi of $NaH^{14}CO_3$ and suspended from a buoy at the depth of collection and incubated for a 4 to 6 hour period. The samples were filtered in the field, placed in scintillation vials, and dried in a dessicator for 24 hours. The activity of the samples was converted to milligrams of carbon per unit area per day using the methods and tables of Saunders et. al. (1962). Samples were not taken in November through January due to difficulties in obtaining carbon-14.

Fish were collected with minnow seines, experimental gill nets, and by electroshocking. Four collections were made from Spencer and Surprise Canyon on 7 March, 29 March, 24 April and 23 May. Other areas in the Colorado River were also seined on the above dates. The shocker was used between Miles 250 and 260 on 26 October, 24 April, and 29 March. An experimental gill net was set at Burnt Canyon on 7 and 29 March.

RESULTS

Temperature, dissolved oxygen, conductivity, and pH measurements at Pierce Ferry and Burnt Canyon are given in Table 1. At Pierce Ferry, water temperatures ranged from 7.0^{o}C in January to 19^{o} in June and were from 2^{o} to 10^{o} cooler than those reported by Anderson and Pritchard (1951). The cooler water temperatures resulting from the effects of Glen Canyon Dam have probably changed the density relationships of the Colorado River and Lake Mead, therefore changing current patterns and limnological conditions in Lake Mead. Water temperatures at Burnt Canyon were always 2^{o} to 4^{o} cooler than Pierce Ferry, and ranged from 6.5^{o} to 14^{o}. Dissolved oxygen varied with water temperature, remaining 90% to slightly super-saturated. Conductivity at Burnt Canyon ranged from 900-1100 michrohoms/cm. At Pierce Ferry higher conductivity levels were found at the surface for some periods, probably due to incomplete mixing of the Colorado River at that point. Hydrogen ion (pH) showed little variation, ranging from 8.0 to 8.5. Lower pH levels were found at Pierce Ferry below three meters.

Turbidity and suspended solids were extremely variable (Table 2). The highest levels occurred in March through May due to spring rains and run off. The highest figure found for suspended solids was 889 mg/l at Burnt Canyon on 23 May. This is comparable to Kubly and Cole's (1976) highest reported value of 986 mg/l at Mile 125 for the same time period in 1975.

Biological oxygen demand and chemical oxygen demand were generally very low (Table 3). These measurements are usually taken in association with waste water and are presented here only as possible guidelines for future studies.

Nutrient concentrations for September through March are presented in Table 4. Results for April through June were not available at the time of writing this report and will be supplemented at a later date. Total phosphorus and nitrogen (nitrate N plus Kjeldahl N) were usually below 60 ug/l and 950 ug/l, respectively. On 3 January, unexplainable high phosphorus concentrations were still evident at Pierce Ferry on 28 January. Vollenweider (1970) states that phosphorus and nitrogen concentrations are extremely variable for different waters but concluded that flowing water with only a slight nutrient load contained less than 100 ug/l phosphorus, and that rivers flowing through mountainous regions contain up to 1000 ug/l of nitrogen. Total phosphorus and nitrogen were usually below these levels and indicate natural conditions.

Total bacteria and total coliform counts (Table 5) were of the same order of magnitude as others reported for the Colorado River (Sommerfeld et. al., 1975). Total coliform counts were higher using Coliform Holding Media and blended samples (Table 6). Blending resulted in dislodging bacteria from particulate material and gave much higher counts. Total coliform counts for 4 January at Burnt Canyon were extremely high (1160/100 ml nonblended sample) as was total phosphorus for the same date, indicating that some form of organic pollutant may have been discharged into the river. Public health standards for recreational waters are based on a fecal coliform limit of 200 organisms/100ml. Fecal coliforms are usually only a small percentage (15-50%) of the total coliform counts (Geldreich, 1970). The samples collected on 4 January may have exceeded recommended levels for fecal coliforms.

Phytoplankton counts and chlorophyll *a* concentrations are presented in Tables 7 and 8. Phytoplankton numbers and chlorophyll *a* concentrations were generally low. Diatoms were the dominant organisms at both stations and showed little seasonal variation. *Diatoma vulgara* had the longest period of dominance (March through June). Only the dominant organisms were identified and counted and, therefore, these counts are not representative of the diversity in the phytoplankton community. Sommerfeld et. al., (1970) have reported a very diverse phytoplankton flora for the Colorado River.

Primary productivity estimations at Pierce Ferry were extremely variable ranging from 17 to 2880 mgC/m^2/day (Table 9). Light penetration appears to be the most important limiting factor. Suspended material is primarily responsible for light attenuation. The lowest primary productivity was found on 25 October, when the surface turbidity was low but the euphotic zone was very narrow (2.5 meters) due to high concentrations of suspended material below the surface. Primary productivity fluctuated in March through May, showing an inverse relationship with turbidity. Production in May was extremely high, comparable to reported values for the Boulder Basin, Lake Mead (Deacon, 1976) and indicate that the system could be very productive.

The location and numbers of fish collected are presented in Table 10. The fish were taken primarily from Spencer and Surprise Canyon. *Fundulus zebrinus* was very abundant at both locations. *Notropis lutrensis* was also abundant in Surprise Canyon. In Spencer Canyon, *F. zebrinus* was generally found in the lower 300 to 400 meter portion of the canyon. Further upstream *Rhinichthys osculus* became more abundant. A large mouth bass (*Mictopterus salmoides*) was observed at the mouth of Spencer Canyon on 23 May. Attempts at collecting fish from the main stream were not very successful. Shocking produced four fish (*Cyprinus carpio*), and only two fish (*Notropis lutrensis*) were taken with the gill net. A few fish were collected from the Colorado River by seining side pools. *Rhinichthy osculus*, *Catostomus latipinnis*, and *Pantosteus discobolus* were the only native fish collected.

CONCLUSIONS

This study was directed primarily at examination of the water quality in the Colorado River. From these data, only a few very broad conclusions can be made. Further research may or may not substantiate these conclusions.

Saturated dissolved oxygen levels, low nutrient concentrations, and bacteria numbers, for all sampling periods except January indicate natural unpolluted conditions. The high phosphorus and total coliform concentrations found on 4 January may possibly have been due to a large organic load discharged into the Colorado River. A continuous monitoring program should be established, sampling at least monthly, or, preferably, weekly, to determine whether or not the conditions found on 4 January occur with any regularity.

Primary productivity appears to be limited by light due to suspended material. The system is potentially very productive if turbidity is reduced. Higher productivity is probably undesirable due to the possibility of phytoplankton blooms and increased periphyton growth.

Although there is not any conclusive data with respect to visitor use, it is suggested that visitor use has minimal or undetectable effects on the overall water quality in the Colorado River. The number of people per week leaving Lee's Ferry in 1974 varied from 242 to 790 (Shelby and Nielsen, 1975). If these figures are representative of the population densities on the river at any one time, dilution alone would be sufficient to minimize direct effects of sewage effluent on water quality. This is especially true since human waste materials are usually buried. Sommerfeld et. al. (1975) has reported high total coliform counts adjacent to some campsites, possibly due to seepage from Porta-potty disposal. Potential health hazards may exist in these areas.

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Table 1. Temperature (°C) dissolved oxygen (mg/l) conductivity (microhoms/cm) and pH at Pierce Ferry and Burnt Canyon.

		Pierce Ferry				Burnt Canyon			
Date	Depth (M)	Temp	O_2	Cond	pH	Temp	O_2	Cond	pH
27 Sept.	0	14.0	10.4	940	8.1				
	1	14.0	10.0	935	8.0				
	2	13.5	10.0	930	8.0				
	5	13.5	10.0	930	8.0				
	6	13.5	10.0	930	8.0				
	7	13.0	10.0	920	8.0				
25 Oct.	0	13.5	10.6	900	8.1	12.0	10.8	1100	8.3
	1	13.5	10.4	950	8.2	12.0	11.0	1100	8.3
	2	13.5	10.3	950	8.2	12.0	11.0	1100	8.3
	3	13.5	10.3	950	8.2				
	4	13.5	10.3	950	8.2				
	5	13.5	10.3	950	8.2				
	6	13.5	10.3	950	8.2				
	7	13.5	10.3	950	8.2				
30 Nov.	0	9.0	11.6	1000	8.3	8.0	12.8	1000	8.5
	1	9.0	11.6	1000	8.3	8.0	12.8	1000	8.4
	2	9.0	11.6	1000	8.3	8.0	12.5	1000	8.4
	3	9.0	11.6	1000	8.3				
	4	9.0	11.6	1000	8.3				
	5	9.0	11.6	1000	8.3				
	6	9.0	11.6	1000	8.3				
	7	8.5	11.6	1000	8.3				

Table 1. continued

Date	Depth (M)	Pierce Ferry				Burnt Canyon			
		Temp	O_2	Cond	pH	Temp	O_2	Cond	pH
4 Jan.	0	7.0	13.0	950	8.2	6.5	13.2	1075	8.3
	1	7.0	12.8	950	8.3	6.5	13.2	1075	8.3
	2	7.0	12.6	900	8.2	6.3	13.2	1075	8.3
	3	6.5	12.4	900	7.4				
	4	7.3	12.3	900	7.3				
	5	7.0	12.2	900	7.4				
	6	7.3	12.2	900	7.4				
	7	7.3	12.2	900	7.4				
28 Jan.	0		12.8	1000	8.4		12.0	900	8.1
	1		12.2	1000	8.4		12.0	900	8.3
	2		12.0	900	8.5		12.0	900	8.4
	3		12.0	950	---				
	4		11.8	950	---				
	5		12.0	950	---				
	6		11.8	1000	---				
	7		11.2	1050	---				
7 March	0	10.5	13.1	950	8.2	8.0	12.9	1000	8.1
	1	10.5	13.1	950	8.2	8.0	12.8	1000	8.1
	2	10.0	13.1	950	8.2	8.0	12.7	1000	8.1
	3	10.0	12.0	950	8.2				
	4	10.0	12.0	900	8.1				
	5	10.0	12.0	900	8.1				
	6	10.0	12.0	900	8.1				
	7	10.0	12.0	900	8.1				

Table 1. continued

Date	Depth (M)	Pierce Ferry Temp	O_2	Cond	pH	Burnt Canyon Temp	O_2	Cond	pH
31 March	0	13.5	11.0	950	8.2	10.5	12.0	1000	8.4
	1	13.5	11.0	1000	8.2	10.5	12.0	1000	8.3
	2	12.5	10.5	1000	8.3	10.5	11.5	1000	8.3
	3	12.5	9.6	1000	8.3				
	4	12.0	10.0	1000	8.2				
	5	12.0	9.6	1000	8.2				
	6	12.0	9.2	1000	8.1				
	7	11.5	9.2	1000	8.1				
25 April	0	15.7	11.3	1000	8.3	14.0	10.6	1000	8.3
	1	15.5	11.4	1000	8.3	13.7	10.6	1000	8.3
	2	15.5	11.9	1000	8.3	13.7	10.8	1000	8.3
	3	15.5	11.9	1000	8.3	13.6	10.8	1000	8.3
	4	15.5	11.9	1000	8.4				
	5	15.5	12.0	1000	8.2				
	6	15.5	12.0	1000	8.1				
	7	13.0	9.3	1000	8.1				
23 May	0	17.5	9.2	950		13.5	9.2	900	8.3
	1	17.0	9.2	950		13.5	9.6	900	8.3
	2	16.0	9.0	950		13.5	9.8	900	8.3
	3	15.5	8.6	950					
	4	15.0	8.1	950					
	5	15.0	8.4	950					
	6	14.5	8.8	950					
	7	14.5	9.5	950					

Table 1. continued

Date	Depth (M)	Pierce Ferry Temp	Pierce Ferry O_2	Pierce Ferry Cond	Pierce Ferry pH	Burnt Canyon Temp	Burnt Canyon O_2	Burnt Canyon Cond	Burnt Canyon pH
10 June	0	19.0	9.6	1000					
	1	19.0	9.6	1000					
	2	19.0	9.6	950					
	3	19.0	9.6	950					
	4	18.5	9.6	950					
	5	18.0	9.4	950					
	6	18.0	9.0	950					
	7	18.0	8.4	950					

Table 2. Turbidity in formazin turbidity units and suspended solids (mg/l) at Pierce Ferry and Burnt Canyon.

	Pierce Ferry		Burnt Canyon	
	Turbidity	Suspended Solids	Turbidity	Suspended Solids
27 Sept.	14.0	38		
26 Oct.	9.3	20	7.5	53
3 Jan.	35.5		445	
28 Jan.	115	143	25	8
7 March	5	2	87	195
31 March	325	525	82	193
25 April	120	188	260	585
23 May	22	48	405	889
10 June	18	15		

Table 3. Biological oxygen demand (BOD) and chemical oxygen demand (COD) in mg/l at Pierce Ferry and Burnt Canyon.

	Pierce Ferry		Burnt Canyon	
	BOD	COD	BOD	COD
27 Sept.	51.7	0		
26 Oct.	2.2	0	1.1	0
3 Jan.	4.4	0	0	0
28 Jan.	0	57.0	0	11.2
7 March	0	61.9	0	0
31 March	0.3	94.8	0	25.3
25 April	0	7.9	0	16.6
23 May	9.4		8.3	57.2
10 June	10.7	7.8		

Table 4. Nutrient concentrations in mg/l at Pierce Ferry and Burnt Canyon. Total P = total phosphorus, Diss P = dissolved phorphorus, NH_3-N = ammonia nitrogen, NO3-N = nitrite plus nitrate nitrogen, TKN = total Kjeldahl nitrogen, Alk = total alkalinity.

Date	Total P	Diss P	NH_3-N	NO_3-N	TKN	Alk
		Pierce Ferry				
27 Sept.	0.029	0.018	<.02	0.55	0.4	151
26 Oct.	0.021	0.005	0.03	0.46	<.2	156
30 Nov.	0.022	0.013	0.03	0.48	0.3	150
3 Jan.	0.320	0.045	0.17	0.41	0.2	158
28 Jan.	0.143	0.030	0.14	0.36	0.2	148
7 March	0.022	0.013	0.03	0.48	0.3	150
31 March	0.056				0.5	
		Burnt Canyon				
26 Oct.	0.013	0.002	0.02	0.45	0.2	166
30 Nov.	0.027	0.008	0.05		0.2	147
3 Jan.	0.488	0.016	0.05	0.38	0.4	160
28 Jan.	0.025	0.009	0.04	0.37	0.2	139
7 March	0.027	0.008	0.05		0.2	147
31 March	0.018				<.2	

Table 5. Total bacteria and total coliform (#/100ml) at Pierce Ferry and Burnt Canyon.

Date	Pierce Ferry		Burnt Canyon	
	Total Bacteria	Total Coliform	Total Bacteria	Total Coliform
27 Sept.	4.24×10^5	180		
25 Oct.	3.64×10^4	12	1.96×10^5	1.6
30 Nov.			6.04×10^4	5.2
4 Jan.	2.9×10^5	58	5.7×10^5	1160.0
28 Jan.	7.58×10^5	44	9.2×10^5	5.0
6 March*	7.33×10^4	392	1.13×10^5	76
31 March	8.8×10^5	680.0	1.46×10^6	340.0
25 April		152		362
23 May	7.1×10^4	192	8.5×10^4	68
10 June	6.42×10^4	72		

*Bacteria counts determined from blended samples (6 March - 10 June).

Table 6. Nonblended and blended total coliform counts using M Endo B and coliform holding media (CHM), 6 March 1976. Number in parenthesis equals 1 standard deviation.

	Pierce Ferry		Burnt Canyon	
M Endo B				
Nonblended	17.8	(6.9)	14.6	(6.9)
Blended	224	(164)	21.2	(8.3)
CHM				
Nonblended	27.6	(10.8)	22.6	(9.1)
Blended	392	(109)	76	(24.1)

Table 7. Dominant phytoplankton at Pierce Ferry and Burnt Canyon.

Date	Pierce Ferry	#/ml	Burnt Canyon	#/ml
27 Sept.	*Carteria sp.*	26		
	Navicula crytocephala	20		
	Cyclotella sp.	13		
	Cyclotella glomerata sp.	13		
	Total	125		
26 Oct.	*Fragilaris crotonensis*	15	*Diatoma vulgara*	36
	Nitzschia sp.	13	*Navicula crytocephala*	18
	Cyclotella sp.	13	*Rhoicosphenia curvata*	18
	Navicula crytocephala	12	*Cyclotella sp.*	8
	Total	98	Total	126

Table 7. continued

Date	Pierce Ferry	#/ml	Burnt Canyon	#/ml
31 Nov.	*Cyclotella sp.*	207	*Rhoicosphenis curvata*	31
	Fragilaria crotonensis	34	*Cyclotella sp.*	30
	Mallomonas pseudo	8	*Diatoma vulgara*	26
	Cyclotella sp.	3	*Cocconeis placentala*	21
	Total	282	Total	174
4 Jan.	*Cyclotella sp.*	197	*Cocconeis placentula*	72
	Fragilaris crotonensis	53	*Navicula gracilis*	53
	Navicula gracilis	46	*Rhoicosphenis currata*	26
	Diatoma vulgara	39	*Cymbella prostrata*	20
	Total	466	Total	217
28 Jan.	*Fragilaria crotonensis*	131	*Rhoicosphenia curvata*	28
	Cyclotella sp.	33	*Fragilaria crotonensis*	20
	Cymbella ventricosa	26	*Cyclotella atomus*	18
	Navicula gracilis	20	*Cocconeis placentula*	15
	Total	315	Total	125

Table 7. continued

Date	Pierce Ferry	#/ml	Burnt Canyon	#/ml
7 March	*Fragilavia crotonensis*	76	*Rhoicosphenia curvata*	79
	Cyclotella sp.	25	*Diatoma vulgara*	79
	Stephanodiscus sp.	12	*Cocconeis placentala*	66
	Glenodinium sp.	10	*Navicula gracilis*	53
	Total	149	Total	295
31 March	*Cyclotella sp.*	66	*Diatoma vulgara*	148
	Cyclotella sp.	53	*Rhoicosphenia curvata*	82
	Cymbella ventricosa	13	*Navicula gracilis*	16
	Cocconeis placentala	13	*Cymbella ventricosa*	16
	Total	170	Total	354
25 April	*Diatoma vulgara*	66	*Diatoma vulgara*	151
	Cocconeis placentala	30	*Navicula gracilis*	40
	Navicula gracilis	13	*Rhoicosphenia curvata*	40
	Rhoicosphenia curvata	13	*Cocconeis placentala*	26
	Total	200	Total	295

Table 7. continued

Date	Pierce Ferry	#/ml	Burnt Canyon	#/ml
23 May	*Diatoma vulgara*	79	*Diatoma vulgara*	85
	Cocconeis placentala	53	*Rhoicosphenia curvata*	69
	Cyclotella sp.	33	*Cocconeis placentala*	43
	Rhoicosphenia curvata	33	*Cymbella ventricosa*	26
	Total	289	Total	256
10 June	*Diatoma vulgara*	31		
	Rhoicosphenia curvata	18		
	Cocconeis placentala	12		
	Cymbella ventricosa	7		
	Total	97		

Table 8. Chlorophyll *a* in mg/m^3 at Pierce Ferry and Burnt Canyon.

Date	Pierce Ferry	Burnt Canyon
27 Sept.	1.032	
26 Oct.	2.181	1.034
31 Nov.	1.293	0.865
4 Jan.	4.060	1.812
28 Jan.	2.848	1.090
7 March	1.410	0.774
31 March	3.480	0.245
25 April	2.734	2.389
23 May	1.732	0.425
6 June	1.221	

Table 9. Primary productivity estimations at Pierce Ferry.

mgC/m^3/day	27 Sept. 1975	25 Oct. 1975	7 March 1976	31 March 1976	25 April 1976	23 May 1976	10 June 1976
1	142.0	14.2	90.0	40.0	50.0	60.0	150
2	75.0	2.6	147.0	94.0	100.0	760.0	80
3	25.0	0.2	149.0	105.0	108.0	1220.0	28
4			100.0	23.0	47.0	600.0	7
5			30.0	3.0	8.0	240.0	
total mgC/m^2/day	242.0	17.0	516.0	265.0	313.0	2880.0	265

Table 10. Fish collected at various locations between Separation Rapids and Pierce Ferry.

Species	Location	Number Collected
Cyprinus carpio (carp)	Mile 253	2
Rhinichthys osculus (speckled dace)	Mile 260	2
	Spencer Canyon	41
	Surprise Canyon	2
Notropis lutrensis (red shiner)	Mile 253	9
	Mile 255	1
	Mile 259	2
	Spencer Canyon	6
	Surprise Canyon	94
Pimephales promelas (fathead minnow)	Spencer Canyon	1
	Surprise Canyon	7
Catostomus latipinnis (flannelmouth sucker)	Mile 255	1
	Surprise Canyon	2
Pantosteus discobolus (bluehead mountain sucker)	Mile 253	1
	Surprise Canyon	1
Fundulus zebrinus (Rio Grande killifish)	Spencer Canyon	81
	Surprise Canyon	113
Gambusia affinis (mosquitofish)	Emery Falls	15
Lepomis cyanellus (green sunfish)	Surprise Canyon	2
Micropterus salmoides	Emery Falls	2

Appendix. Flowering plants collected at Spencer Canyon, 1976.

Family Boraginaceae
Amsinkia tessellata Gray
Cryptantha angustifolia (Torr.) Greene
Cryptantha barbigera (Gray) Greene
Cryptantha utahensis (Gray) Greene

Family Compositae
Baileya multiradiata Harv. & Gray

Family Cruciferae
Arabis pulchra Jones
Lepidium fremontii Wats.
Lesquerella palmeri Wats.
Rorippa sinuata (Nutl.) A. S. Hitch.
Stanleya pinnata (Pursh) Britton

Family Gramilleae
Bromus arizonicus (Shear) Stebbins

Family Hydrophyllaceae
Phacelia crenulata Torr.

Family Labiatae
Salvia Columbariae Benth.

Family Malvaceae
Sphaeralcea ambigua Gray

Family Onagraceae
Oenothera clavaeformis Torr. & Frem.

Family Ranunculaceae
Aquilegia chrysantha Gray

Family Scrophulariaceae
Mimulus cardinalis Dougl.